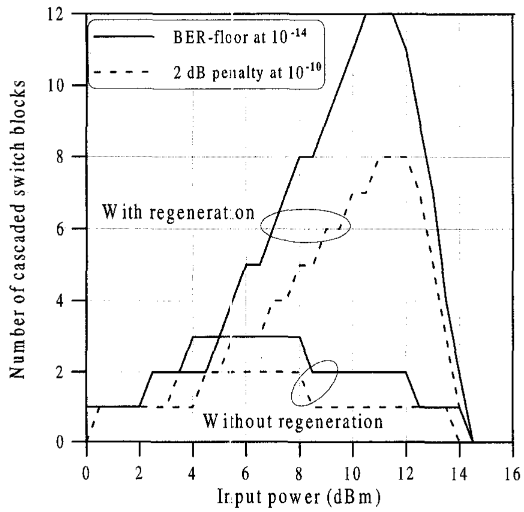

WH5 Fig. 3. The maximum number of cascaded switch blocks as a function of the switch input power at 10 Gbit/s; both with and without regeneration in the IWCs.

increasing the switch size the beneficial effect from the IWCs is still significant. The overall maximum number of cascaded switch blocks is assessed to eight at a BER floor of 10^{-14} for an 8 × 8 switch block while only two switch blocks in cascade are possible without the regeneration. Finally, the corresponding numbers for a 16 × 16 switch block is four with regeneration and two without.

In conclusion, it is demonstrated that the use of IWCs in the broadcast and select packet switch block results in an improved cascadability. Furthermore, it is predicted that successful concatenation of eight 8 × 8 and four 16 × 16 switch blocks is possible.

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WH6 2:45pm

Cascaded wavelength conversions using four-wave mixing in semiconductor optical amplifiers

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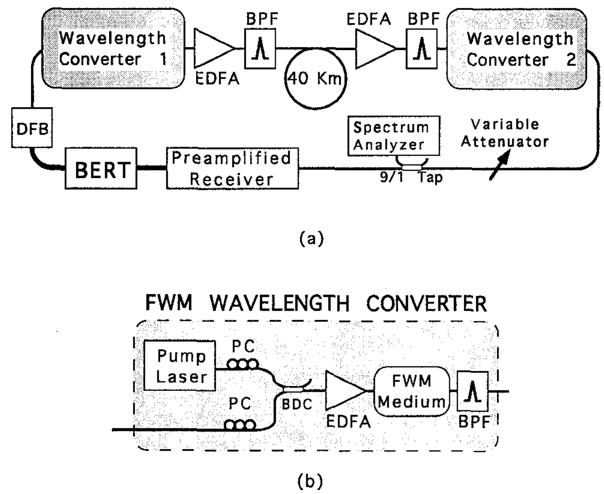
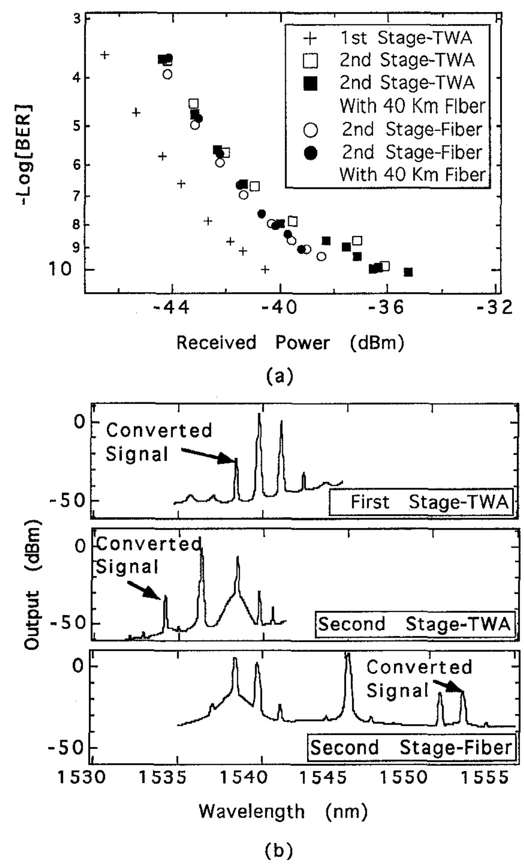
Wavelength conversion in wavelength-division multiplexed (WDM) communication systems would provide significant network performance improvement.[1] Optoelectronic, cross-gain saturation, and cross-phase saturation wavelength converters are candidate technologies that have been well characterized,[2] however, they are not "transparent" to either bit-rate or modulation format. Complete transparency is offered only by ultrafast wave mixing techniques—in the present case four-wave mixing (FWM) in semiconductor optical amplifiers (SOAs). To date,



WH6 Fig. 1. (a) System diagram. (b) Details of the wavelength converter. FWM medium is an SOA in Converter 1 and either an SOA or a 4.4-km segment of dispersion-shifted fiber in Converter 2.

demonstrations of noncascaded, SOA FWM wavelength conversion have shown negligible degradation to the system performance for bit rates up



WH6 Fig. 2. (a) BER vs. received power data for the various systems demonstrated. (b) Output spectra (0.1-nm resolution bandwidth) of the FWM element for the various wavelength converters.

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to 10 Gbit/s.[3] However cascading is necessary for implementation of converters in scalable WDM networks. Here we present the first demonstration, to our knowledge, of a system utilizing cascaded SOA FWM wavelength converters.

The system, shown in Fig. 1(a), uses a bit-error-rate test (BERT) system generating a 2.5-Gbit/s PRBS of NRZ ASK data. This signal directly drives a distributed feedback laser. The final signal is detected by a preamplified receiver, preceded by a variable attenuator and a tap. Our wavelength converter, shown in Fig. 1(b), combines the input signal with a pump laser in a bidirectional coupler (BDC). Mechanical polarization controllers (PCs) are used to align pump and signal polarizations. These waves are then amplified in a high-power erbium-doped fiber amplifier (EDFA), coupled into the FWM medium, and passed through an optical bandpass filter (BPF) to suppress the original signal and the pump.

Several experimental configurations are demonstrated, with corresponding BER versus received power data and FWM medium output spectra shown in Fig. 2. For comparison purposes, the first stage of the cascade (Converter 1) is characterized separately. This stage provides wavelength conversion of 3 nm utilizing an SOA as the FWM medium. The converted signal has an optical SNR of 26 dB into 0.1 nm, as can be seen in the upper panel of Fig. 2(b). To enable cascading with Wavelength Converter 2, an EDFA-BPF pair is inserted at Converter 1's output to boost the power level of the converted signal. An SOA FWM element is used in Converter 2, giving a 4-nm shift. This results in a decrease of the SNR at the output of the second converter to 23.4 dB, as shown in the center panel in Fig. 2(b). No additional degradation is observed when 40 km of fiber (followed by an EDFA-BPF pair at its output to compensate for propagation loss) is inserted between the converters to simulate a multitap cascade along a trunk line.

We repeated the experiment using 4.4 km of dispersion-shifted fiber as the FWM medium in Wavelength Converter 2. The pump wavelength in this case is set for a 14-nm conversion. A SNR of 22.3 dB is obtained, shown in Fig. 2(b). Again, no additional degradation is observed when 40 km of fiber is inserted between the converters.

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WH7 3:00pm

Comparison of DSF- and SOA-based phase conjugators employing noise-suppressing fiber

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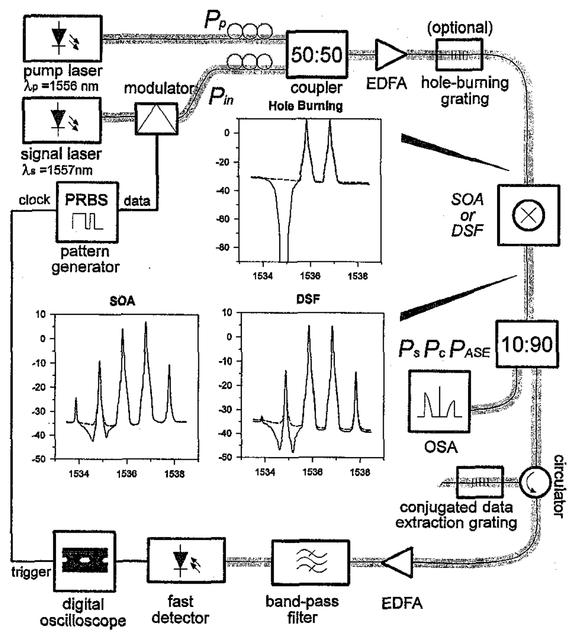
Dispersion-shifted fiber (DSF) and semiconductor optical amplifiers (SOAs) are the most desirable phase conjugators for optical fiber communication and may be used for dispersion compensation and wavelength conversion. Amplified spontaneous emission (ASE) from the pump and signal source has been recognized as a limitation to phase conjugation, and is usually suppressed by bandpass filtering the pump and signal source before combining them.[1] More recently, it has been suppressed by a bandstop filter at the conjugate wavelength, after combining pump and signal light.[2]



WH7 Fig. 1. System diagram.

In this paper, SOA- and DSF-based conjugators are compared using identical fiber-grating-based filter networks and 10-Gbit/s nonreturn-to-zero (NRZ) intensity-modulated data. We believe we report for the first time the use of fiber gratings for efficient ASE filtering and signal extraction. We identify ASE from the amplifiers, rather than the conjugation efficiency, as the limitation to phase conjugation in both approaches. Although the SOA provides a larger conversion efficiency for the same input powers, the optical signal-to-noise ratios (SNRs) are similar for both the SOA and DSF conjugators. However, because a larger input signal can be employed for the DSF before distortion sets in, the best performance is obtained with the DSF.

A schematic of the system is shown in Fig. 1. The signal light (λ_s = 1537 nm) is modulated with a $2^{31} - 1$ pseudorandom binary sequence via a chirp-free Mach-Zehnder modulator. The signal is combined in a 3-dB coupler with a pump signal (λ_p = 1536 nm). An erbium-doped fiber amplifier (EDFA) with output power of ~10 dBm increases the available power at the phase conjugator. The conjugated signal (λ_c = 1535 nm) is extracted from the pump and signal by a circulator and a fiber grating centred at λ_c with a bandwidth of 0.5 nm. The close wavelength spacing of the pump and signal is allowed by the sharp cutoff of this grating. The circulator output is amplified with an EDFA, and out-of-band ASE filtered with a polarization-insensitive bandpass filter. The data is received with a 6.4-GHz bandwidth detector and the eye diagram examined on a digital oscilloscope.

Both a GaInAsP SOA (Alcatel A 1901 SOA) and 13 km of DSF are compared as phase conjugators. The wavelength of the pump is selected to match the zero-dispersion wavelength of the DSF (λ_0 ~ 1535 nm) and the pump power chosen below the stimulated Brillouin threshold in the DSF.[3] Optionally, a second strong grating was used to burn a deep spectral hole of 1.2-nm bandwidth at λ_c to suppress the ASE before the conjugator by >40 dB (see spectra in Fig. 1). This grating acts as a bandstop filter to suppress the ASE before the DSF or SOA conjugator, a similar technique was previously reported for an SOA conjugator.[2] We